

Models of Scientific Activity

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Global Seminar Held in New Delhi

One hundred scientists and engineers from about 40 countries from all over the world participated in a global seminar on the Role of Scientific and Engineering Societies in Development, held in New Delhi, India, 1-5 December 1980. Principal co-sponsors with AAAS were the Indian Science Congress Association (ISCA) and the Indian National Science Academy (INSA). Financial support was provided by the co-sponsors and other organizations, including the U.S. National Science Foundation and the Indian Department of Science and Technology.

Participants were drawn from scientific

and engineering societies around the world. Professional societies in engineering and in the physical, biomedical, and social sciences and from industrialized and developing countries were represented in approximately equal numbers. The larger national delegations were from India, the United States, the Soviet Union, and the People's Republic of China. Twelve of the 22 U.S. delegates were from member societies of the AAAS Consortium of Affiliates for International Programs.

The seminar was cochaired by Kenneth R. Boulding, outgoing chairman of the Board of Directors, AAAS, and A. K. Sharma, president, ISCA. Three plenary speakers related the seminar objectives to the major disciplinary fields represented. Y. Nayakdutta, chairman of

the Committee of Science and Technology in Developing Countries (COSTED) of the International Council of Scientific Unions (ICSU), spoke for the physical and biomedical sciences. Boulding for the social sciences; J. De Becker, representing the Deutscher Verein Technisch-Wissenschaftlicher Vereine (DVT), spoke on behalf of the World Federation of Engineering Organizations and the engineering societies.

Participants spent most of their time in working groups where they identified the unique characteristics of the scientific and engineering societies in diverse economic and political structures and considered how the societies could help solve problems of development. Each working group presented its own report including conclusions and recommendations.

Scientific planning and evaluation are hotly disputed subjects; they often lead to the confrontation of two opposite and abstract notions about how the scientific work is or should be organized, understood and justified. The first notion emphasizes academic research as the one more able to lead to intellectual development and creativity of the scientific community, which in turn could provide the development of applied research and technology as byproducts. The second favors applied research as the only way to establish effective links between scientific research and social and economic needs. In the latter's view, academic research should be considered only as an eventually necessary input for the improvement of applied work.

The abstract confrontation between these two notions tends to ignore the reality in which the scientists actually work, which is the result of a series of demands, expectations and aspirations that seldom converge. Scientists are called to do academic research, to teach at undergraduate and graduate courses, are concerned with the social consequences of their work, take care of their professional careers and look for jobs where payment is satisfactory. Not all of these activities add up: to teach takes time away from research, academic

research can be good for professional advancement but may be socially irrelevant, and vice-versa; well-paid jobs can be less prestigious, and so on and so forth. Moreover, it is fairly clear and generally accepted that there are no clear-cut definitions and precise boundaries between "academic," "applied" and "basic" research. The meanings of these terms change according to the discipline, the country, the epoch and the person that uses them¹. In fact, the same type of scientific activity can be called by one or another of these terms depending, for instance, on the agency that supports it or the institution where it is carried on.

¹ Otto Mayr, "The Science-Technology relationship as a Historiographic Problem", *Technology and Culture*, 17 (4), 1976

The complexity, diversity and differentiation of scientific activities should not lead us to abandon the attempts to understand and explain how these activities are carried through according to some well-defined conceptual framework. If we can do this, the debate about scientific planning and evaluation can probably benefit.

The best approach to this conceptual clarification is to describe how scientific activities are performed according to some "ideal types," or models, that can function as parameters to compare with the empirical realities. Ideal types are theoretical constructs that attempt to reconstruct the logic of human action in a given area of endeavor, by deriving all the logic all consequences of a given set of explicit values and goals². Ideal types do not describe the empirical reality, but allow for comparisons to be made and propositions to be put forth when the relative proximity of a given reality with a given model is ascertained. Ideal types are very useful to clarify the meaning of human actions in terms of their values and motivations, and therefore to understand and evaluate specific historical events. Two of the ideal types we shall present below are derived from the two opposite notions referred to at the beginning. To them we shall add a third, which is less frequently observed in the literature, but also quite relevant.

The more widely known ideal type among sociologists of science the one of the "republic of science"³. According to this model, scientific activity is chiefly concerned with the improvement of knowledge, and has a system of rewards, prestige and sanctions that depend on the relative success of the scientists in this task. The reasons why people value empirical knowledge are irrelevant for the model; what matters is that knowledge must be something considered worthwhile in itself, rather than a means to other ends. The evaluation of quality and value of this knowledge depends on the existence of a group of people that are able and legitimate to make it. They form what is called a "scientific community." Scientific communities are in many ways like any other professional corporations: they develop internal criteria of prestige, authority and merit, and use them to control the entrance and exit of their members. They control their own institutions - specialized journals, professional associations, university departments, research units - and have a crucial role in the distribution of resources within the community.

Internally, these communities are organized as meritocratic republics. They are stratified along the lines of intellectual merit, which is established in a free "market" of information dissemination. The scientist gets the rewards for his work, in terms of prestige, authority and material goods, through the dissemination of his work and its acceptance by his colleagues. This market of information requires, in turn, some consensus among the community about what is a relevant scientific work and what is not, as well as about the criteria for deciding whether a research work was done properly and if some kind of "truth" have been achieved. This consensus is referred to in the literature as a "paradigm," a word which summarizes the set of theories, information, methodologies, working patterns, criteria of quality and b assumptions that characterize a given area of scientific knowledge. Paradigms are not, therefore, just a scientific theory, but take into account a group of real-life persons working within the boundaries of a given framework⁴.

The problem of the actual range and types of paradigms does not concern us here. What is important is the idea that scientists tend to work within relatively small communities, where their merit is acknowledged, and where they learn what they know and form their students and disciples. Sociologists of science have called these communities "invisible colleges," which although not formally organized, provide the basis for organization, continuity and development of scientific research⁵.

² Max Weber, *The Methodology of Social Sciences*, The Free Press, Glencoe, 1949

³ Michael, Polanyi. *Personal knowledge - towards a post-critical philosophy*. Routledge & Kegan Paul, London, 1962; "The Republic of Science its political and economic theory", in Edward Shils (ed). *Criteria of scientific development*. MIT Press, Cambridge, 1968. Robert K. Merton, *The sociology of science: theoretical and empirical investigations*. (edited by Norman Storer) Chicago University Press, 1973.

⁴ Thomas S. Kuhn, *The structure of scientific revolutions*. Chicago University Press, 1962.

⁵ Diana Crane, *Invisible colleges (diffusion of knowledge in scientific communities)*. Chicago University Press, 1972.

The basic theorem that follows from this ideal type is that scientific research is by necessity a self-regulated and free activity, and that any attempt to tinker with its mechanisms of self-central and inner-directedness can only jeopardize its quality and performance. The consequences of this theorem for the question of scientific planning and evaluation are easy to imagine.

The second ideal type can be called the "technical progress model." Its basic axiom is that the central aim of scientific activity is to solve the practical and utilitarian problems confronted by human society in its different forms and stages of social and economic development. In this sense, science is not very different from other forms of knowledge. Eventual dissociations that occur between science, technology and practical knowledge should be viewed, in this perspective, as alienations⁶. They can sometimes veil, but cannot possibly eliminate the necessary ties between knowledge and its social use. Thus, the "republic of science" ideal type should be considered as an ideological manifestation of the dissociation between manual and intellectual labor, which is a product of class societies. The role of sociology of knowledge, still according to this second ideal type, should be the establishment of causal links between the types of knowledge generated by a given society and its social and economic organization.

Once this task is accomplished, dissociations between science, technology and practical knowledge should disappear. This would open the way for planning science and technology according to social and economic needs. The researcher would choose his field and subject according to some criteria of social utility, and would be rewarded accordingly. This reward would have a monetary value which is paramount to the economic relevance of the findings. The product of research would have, by definition, an exchange value that can be estimated, and not only a use value, as knowledge in itself. It could, therefore, be exchanged by other goods or privileges, such as royalties, licenses or monopolistic control of its products. How the scientist relates with the product of his work would be a function of the more general organization of society's productive system. In less developed societies, the researcher could often exploit his findings as an individual entrepreneur. In more complex, capitalist societies, he would tend to be a qualified worker, whose product is appropriated by his employer.

In short, the "technical progress model" sees scientific activity as part of the more general economic and productive activity of a given society. The implications of this model's adoption for the establishment of scientific policies, as well as for the organization of the scientific work, are also easy to conceive.

The third type is the "big science" model. It sees scientific activity as part of the complex structures of modern, large-scale organizations. Its historical reference is not the work of the individual scientist in his republic nor the technology of the isolated discoverer, but the large techno-scientific organizations of today. According to this perspective, modern scientific activity has little in common with science and technology of the past, which makes the study of the history of science and technology fairly irrelevant: modern science would be as different from its past as modern industry is from the handicrafts from centuries ago. As a participant in the large organizations of modern science, the scientist would follow the behavior patterns that are typical of these organizations. Division of labor, well-defined goals and organizational controls would substitute for the more informal and inspirational patterns of the individual scientist or technologist of the yesteryears.⁷

One of the basic axioms of this model is the notion put forward, among others, by John Kenneth Galbraith, that organizations tend to grow and to strengthen themselves as far as possible⁸. One of the main tools for this is the maximum possible control they establish over their external environment, in such a way that an "inverted sequence" is established: the large-scale organizations cease to follow the demands and pressures of the environment, and start to mold them to their convenience.

⁶ John D. Bernal, *Social function of science*. MIT Press, Cambridge, 1939.

⁷ Donald Pelz and Frank M. Andrews, *Scientists in Organizations*, Wiley, 1976; David Joravsky, *Soviet Marxism and Natural Science, 1917/1932*, Routledge & Kegan Paul, 1961; and D. Joravsky, "Scientists as Servants", *New York Review of Books*, June 28, 1979.

⁸ John Kenneth Galbraith, *The New Industrial State*, Boston, Houghton Mifflin Co , 1967.

In this context, the motivation of the scientific work would cease to be conditioned either by the peer group's expectations or by the eventual practical and economic utility of his work; only the internal appreciation of the organization's high echelons would matter. This appreciation would depend, in turn, on the broader goals of the organization. Industrial corporations would tend to favor research more approximated to the technical progress model, while independent research institutes would value research that is closer to the academic model. Large governmental institutions concerned with technological research however, are the best approximations of this model. Atomic, space, agricultural, and medical research centers and institutes are emerging today in almost all countries, supported by the respective governments, and kept relatively aside from the University and the industrial communities. The quality of their research can vary from excellent to dismal. They are relatively free from sanctions from either the scientific "invisible colleges" or the market pressures.

It is possible to suggest that each of the three types above leads to a different kind of scientific activity. For the sake of this discussion, we can call "academic research" the scientific work which is motivated by the search of important empirical facts and theories that can advance a given field of knowledge, according to the consensus of the relevant community of specialists. By "applied research" we shall call the scientific activity that has some practical relevance besides and independently of knowledge in itself; and we shall call "basic research" the scientific activity that is geared to the accumulation of knowledge and information that may eventually lead to relevant academic or applied results, but without searching for them directly. We can notice that these distinctions are based on the attitudes of the scientist regarding his work, and not on the characteristics of the work in itself, where such distinctions would be impossible. The relations between these three "types" of science and the three models of scientific activity are summarized in the table below.

The last line of the table indicates the "typical" scientific activities that can be expected to follow from each model. The "republic of science" model favors a more academic environment, based on the individual freedom of the scientists, free flow of scientific information, and so on. The "technical progress" model leads to the subordination of scientific activities to explicit goals, which are in turn selected by their economic or social utility. The "big science" model, finally, is geared to the massive accumulation of knowledge and information that could be absorbed and utilized by the large organizations where this activity takes place. More often than not, these are governmental agencies of different kinds.

IDEAL MODELS OF SCIENTIFIC ACTIVITY			
	"Republic of science"	"Technical progress"	"Big science"
Goals	Knowledge for its own sake	Social and economic utility	Organizational growth and strengthening
Criteria of evaluation	By the consensus of the scientific community	Through market mechanisms	Through acknowledgment within the organization
Rewards system	Academic prestige and related benefits	According to the exchange value of technological products	Organizational and bureaucratic power
Appropriation of the product of scientific work	By acknowledgment through diffusion within the scientific community	Patents and other forms of proprietary research	By the organization
Type of science produced	"Academic" science	"Applied" science	"Basic" science

The important question is the following: which model of scientific organization has been dominant in a given society, and which one should be favored? We know, of course, that the three "types" coexist very often in the same country, within the same institutions and sometimes even within the same individual researcher. In spite of this, we can expect that an excessive dominance of the first model could lead to a country's inability to establish some explicit policy of scientific priorities; the second model, on the other hand, could lead to the extinction of independent research and loss of quality, if carried on to its extreme;

the last model, in turn, can eliminate from research its more creative and exploratory characteristics, and transform it in just another ingredient in the activities of large organizations.

The proper implementation of a good system of planning and evaluation of scientific activities require the establishment of equilibrium between these three models, with the clear notion that they should balance each other. This balancing is usually implicit, and carried on through the constant conflicts and debates among different groups about the "true" character of modern scientific activity. To make explicit and systematic these tendencies and differences can probably help to make the process of policy formation more intelligible and, hopefully, more successful.